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ABSTRACT

The Computer-Assisted Instruction Study Management System (CAISMS) was developed and implemented on the PLATO system to monitor and guide student study of text materials. It administers assignments, gives quizzes, and automatically keeps track of a student's progress. This report describes CAISMS and several hypothetical implementations of CAISMS by other means--(1) a manual system without computers, and (2) a computer-managed system, including a batch-oriented computer system with a computer operator interfacing the students and the computer; a time-sharing system similar to PLATO but not instruction-oriented; a minicomputer system running 20 to 30 terminals used only for CAISMS delivery; and a microcomputer system with one small computer per student. Finally, the report describes how CAISMS was implemented in a university economics course and a community college history course, and how it might be implemented in two Navy courses--interior communications and air conditioning/refrigeration. (Author)

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ALTERNATIVE DELIVERY SYSTEMS FOR THE
COMPUTER-AIDED INSTRUCTION STUDY MANAGEMENT SYSTEM (CAISMS)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) CAISMS (Computer-Assisted Instruction Study Management System) is a system for automatic study management implemented on the PLATC IV system at the University of Illinois. This report discusses alternative configurations for delivering CAISMS varying from general-purpose time-sharing systems to a stand-alone terminal based on a microcomputer.		

FOREWORD

This study was performed under a contract to the University of Illinois. It was supported jointly by Exploratory Development Task Area (Methodology for Development and Evaluation of Navy Training Programs, Work Unit Number PF55. 522.002.01.60) and by the Advanced Research Projects Agency (Account Symbol 9740400.1311). The study describes alternate means and provides cost information for delivering a successful computer-based system for managing students' studying of training materials and testing.

Results of this study are intended for use by the Chief of Naval Education and Training, the Chief of Naval Technical Training, and the Chief of Naval Education and Training Support.

Dr. William E. Montague was the technical contract monitor.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

The Computer-Assisted Instruction Study Management System (CAISMS) was developed and implemented in a course at the University of Illinois on the PLATO computer-based educational system. Since this system is not readily available for Navy training, alternative systems for delivering CAISMS must be considered if CAISMS is to be used for Navy training.

Objective

The objective of this study was to identify systems readily available, either now or in the near future, which could be compared in terms of the manner, effort, and cost involved in implementing CAISMS.

Approach

The report briefly describes CAISMS, a computerized procedure for monitoring and guiding student study of text materials. CAISMS administers assignments and gives quizzes and automatically keeps track of a student's progress. Then several hypothetical implementations of CAISMS by other means are considered: (1) a manual system administered by clerks without any computer hardware/software, which is discussed simply for comparative reasons and (2) computer-managed systems, including a batch-oriented computer system with a computer operator interfacing the students and the computer, a large-scale time-sharing system similar to PLATO but not an instruction-oriented machine, a minicomputer system running 20 to 30 terminals used only for CAISMS delivery, and a microcomputer system whereby a single student has a small computer available to him that is designed specifically for CAISMS delivery. Finally, the report describes how CAISMS was implemented in two courses (a university economics course and a community college history course), and how it might be implemented in two Navy courses (interior communications and air conditioning/refrigeration).

Conclusions

Consideration of the two Navy courses supports the contention that the system must be determined to some extent by the materials, procedures, and student characteristics of a particular course, coupled with an analysis of economic factors and expected future uses of computers in many modes of instruction. If CAISMS is to be implemented on a system other than PLATO in the near future, but in a similar manner, the best system would be of the dedicated minicomputer variety. However, in the long run, it would be wise to begin investigating the development of personalized microcomputers for the management of student study from text and other instructional activities.

Recommendations

A test and evaluation of a minicomputer implementation of CAISMS is recommended. Also, further research is recommended regarding the development of a personalized microprocessor system for delivery of CAISMS and other forms of instructional management.

CONTENTS

	Page
INTRODUCTION	1
Problem	1
Objective	1
Background	1
CAISMS FUNCTIONS AND COMPUTER REQUIREMENTS	3
CAISMS Functions	3
Assignment Selection and Delivery	3
Quiz/Test Delivery and Feedback	3
Recordkeeping	4
Computer Requirements	4
Administrative Software	4
Miscellaneous Course Management Features	4
DIFFERENT CONFIGURATIONS FOR DELIVERING CAISMS	7
Manual System	7
Computer-Managed Systems	8
Batch System with Fast Turnaround	8
Time-Sharing System	8
Dedicated Minicomputer for a CAISMS Classroom	9
Personal Microcomputer	10
SOME REPRESENTATIVE COURSES USING CAISMS	13
Introductory Level University Course	13
Introductory Level Community College Course	13
Navy Training Courses	14
MATCHING THE DELIVERY SYSTEM TO THE AUDIENCE	17
CONCLUSIONS	19
RECOMMENDATIONS	21
REFERENCES	23
DISTRIBUTION LIST	25

INTRODUCTION

Problem

The Computer-Assisted Instruction Study Management System (CAISMS), which has been used during several semesters at the University of Illinois, has had a positive effect on student performance in college courses. It has been running on the PLATO IV computer-based instructional system at the university. Due to the high cost and low availability of PLATO, examination of the alternative measures of delivering CAISMS is necessary.

Objective

The objective of this study was to identify systems, readily available now or in the near future, which could be compared in terms of the manner, effort, and cost involved in implementing CAISMS.

Background

The CAISMS was designed to facilitate individual study or instructional materials (Anderson, Anderson, Dalgaard, Paden, Biddle, Surber, & Alessi, 1975; Anderson, Anderson, Alessi, Dalgaard, Paden, Biddle, Surber, & Smock, 1975; Alessi, Anderson, Anderson, Biddle, Dalgaard, Paden, Smock, Surber, & Wielecha, 1974). Under CAISMS, a student signs in on a computer terminal and receives a four- to eight-page reading assignment. He then leaves the terminal and studies the materials in a nearby workspace. When he is finished, he again signs in and receives a short quiz on the assignment. If his quiz score is 75 percent or better, he is given a new assignment. If his quiz score is below 75 percent, he must retake the quiz after a 7-minute programmed delay intended to encourage students to restudy the material.

The rationale for designing CAISMS is that learning from test (or other prepared instructional materials) involves a series of student-initiated processing activities that are seldom fully effective because of conditions prevailing in typical lecture-discussion-type courses. First, of course, the student must study the instructional material. In most courses, there is no way to ensure that students do all the required reading. Undoubtedly, many do not. While CAISMS quizzes are not used for grading, a student must complete a quota of them before he is eligible to take graded examinations. Thus, using this system, it is virtually impossible for a student to go into an examination unprepared.

In addition, included in the rationale is the idea that learning is facilitated by procedures that increase the likelihood that students attend to, search for, and think about important material in the instructional material. From among several procedures that have proven successful in the laboratory, one of the most promising, which is the core of CAISMS, is to question students after they have studied short segments of the materials. The type of questions asked assist in focusing students' attention on certain aspects of the content without exhaustively questioning them about all relevant content (Anderson & Biddle, 1975).

An advanced computer-assisted instruction system, PLATO IV at the University of Illinois, was programmed to deliver CAISMS. Subsequent

sections of this report describe two computer resource requirements imposed by implementing CAISMS, several alternative delivery systems, and representative implementations. A rationale is given for matching the type of course structure with a delivery system and recommendations for further implementations are made.

CAISMS FUNCTIONS AND COMPUTER REQUIREMENTS

CAISMS Functions

There are three basic CAISMS functions: assignment selection and delivery, quiz/test delivery and feedback, and recordkeeping. These functions are described below and an estimate of the amount of storage they require when CAISMS is used to deliver one course is made.

Assignment Selection and Delivery

Before the student is quizzed on material he has studied, he receives an assignment on line specifying the material to be tested on the next quiz. Since assignments are typically an indication of pages in a text to be read, they can be stated very concisely (generally such assignments require 10 to 20 characters). When the student has to study pages from several texts, the statement of an assignment must be somewhat longer, but it is reasonable to set a limit of 100 characters on the length of any one assignment. A course averages 50 to 100 assignments, thus making the assignment file 500 to 10,000 bytes (a byte = one character) of data, with typical values ranging from 2000 to 5000 bytes.

There are advantages to having assignments on line rather than using a course syllabus or weekly handouts. The main advantage is that it encourages reading of material immediately before a quiz on that material. Results of instructional research indicate that this approach to quizzing facilitates learning, and, hence, it is one of the underlying principles of the study management system. Receiving all assignments early in a course encourages students to read large amounts of material at one sitting and then attempt to take many quizzes at once. Although this will still occur, on-line assignments probably increase the frequency of students reading or reviewing the relevant material for a quiz immediately before the quiz. Less theoretically important advantages include the ease of changing assignments in mid-stream and the possibility of providing different assignment sequences to individual students based on performance, interest, etc. Of course, these advantages must be weighed against the disadvantages of on-line assignments. The storage of assignments is one disadvantage although the space required is small in comparison to that required for storage of quizzes. Of more concern is the students' access to assignments. In a time-sharing mode, this is no problem; however, in a batch mode, waiting for assignments may be bothersome enough as to warrant off-line assignments.

Quiz/Test Delivery and Feedback

After the student has read the appropriate assignment, he receives a criterion quiz on that material. The quiz must be retaken if the criterion is not attained. A course will have as many quizzes as assignments, from 50 to 100 in most courses, with an average of four to ten items (multiple-choice or short answer questions) per quiz. A particular implementation may employ alternate forms of quizzes for retakes or simply give the same quiz with a different ordering of the items. An item (question and answer) contains from 100 to about 1000 characters, with an average of 500 characters. Hence, the item file would be on the order of 20,000 to 1,000,000 bytes.

Recordkeeping

In regard to this component, consider only the minimum data an instructor might collect on each student using CAISMS. General information such as the student's name, hours on line, number of sessions, etc. would require perhaps 100 bytes per student. Storage of the number of quizzes completed and the dichotomous item data (DID) for all items received (i.e., for each item taken whether it was answered correctly or incorrectly) would be collected for at least the first administration of each quiz to a student. That would require one bit per item or from 26 to 126 bytes of storage for DID and the number of quizzes completed. Assuming most instructors would want to collect other data (e.g., DID for retakes of quizzes), a reasonable estimate of record storage is 100 to 500 bytes per student. Considerably more storage would be required if instructors desired to store students' answers to items (in contrast to DID), dates quizzes were taken, etc.

Computer Requirements

Administrative Software

A program to administer all three basic functions of CAISMS would require storage in the range of 10,000 to 30,000 bytes, depending on the computer used. The amount of processing required by this program is so small as to be negligible, but can increase on computers with small core memories.

Miscellaneous Course Management Features

As mentioned previously, there are a number of other features that may be programmed and handled on line in conjunction with the study management system. These include test administration and grading, overall course grading, class and exam scheduling, review quiz administration, communications between instructors and students, cumulative feedback to students on their course progress, and course information. Some of these are easy to implement and require little storage (e.g., communications), while others (e.g., scheduling and examinations) require more extensive programming and storage. Although such features may be advantageous and would not always add appreciably to the cost of an implementation of CAISMS, we do not consider them central to the system and will not consider them in our discussion of the suitability of various hardware configurations for the delivery of CAISMS. The previous estimates on program and data storage requirements for assignments, quizzes, and records, which may be considered the requirements for the basic elements of CAISMS within some larger off-line course structure are summarized in Table 1. The next section describes various representative hardware systems that might be considered for the implementation of CAISMS.

Table 1
Estimated Storage Requirements
(In Bytes)

Level of Estimate	Low	Typical	High
CAISMS Driver Program	10,000	20,000	30,000
Quiz and Assignment file for one course	50,000	200,000	1,000,000
Records (one student for one course)	100	500	1,000
Total	60,100	220,500	1,031,000

DIFFERENT CONFIGURATIONS FOR DELIVERING CAISMS

In this section we describe the mode of operation, and estimate the cost of implementation efforts for delivering CAISMS on a variety of systems. Estimates of costs of implementation efforts must necessarily be interpreted with a wide margin of tolerance, since many of the conditions that determine these costs are left unspecified (for example, whether we are speaking of one system or many identical ones, one course taken by many students, or many different courses each taken by a few students). Nevertheless, these estimates give the correct order of magnitude, and they allow comparison of the different systems. The estimates, furthermore, are based primarily upon programming and equipment expenditures. Since item and test development expenditures are assumed to be relatively system independent, they are constant across the various modes of delivery. In what is essentially a comparative report, therefore, they need not be considered.

Manual System

To illustrate the essential functions a computer performs in delivering CAISMS, let us consider a hypothetical system where CAISMS is administered manually, without the use of a computer. We do not think this is a desirable mode of operation; we discuss it to illustrate certain principles.

In a manual system, students might receive a list of all assignments at the beginning of the course, logistics might be handled by posting messages on a bulletin board, and quizzes might be administered as follows. A student receives a multiple-choice-question quiz from a clerk, and marks boxes or punches holes in the paper to indicate his answers. The clerk grades his quiz at a glance by superimposing a master sheet with the correct answers over the student's form, and then records the student's score on a chart. Such a system could be quite efficient if run on a large enough scale; that is, with sufficient numbers of students so that they arrive at the clerk's window at a fairly uniform rate. If there are too few students in the course, the clerk will be idle much of the time, and queues may build up at other times. Because a quiz cannot easily be composed on the spot (i.e., by selecting items from a pool), many different quizzes that cover the same topic must be prepared in advance. In order to amortize the cost of preparing many quizzes, the number of students must be large.

By comparing this hypothetical manual operation with delivery systems based on a computer, where "idle time" may cost little or nothing because the computer is busy performing jobs unrelated to CAISMS, and where random selection from a small pool of questions can produce many different quizzes, one concludes that a main advantage of a computer is that it allows CAISMS to run economically with small numbers of students. This is not to say that CAISMS is inefficient in courses with large numbers of students. Rather, it merely points out that a computer may permit the efficient use of CAISMS even when there is only one student in a given course at a given location.

Computer-Managed Systems

In the following discussion, we will not consider the computerization of general course logistics but, rather, only the basic function of CAISMS: administration of assignments, quizzes, and recordkeeping.

Batch System with Fast Turnaround

On a batch system that provides instant turnaround (a few minutes) to short jobs, the following mode of operation becomes possible. When a student hands in an ID card or types his identification at a terminal, CAISMS prints out his next assignment or quiz. The student answers the questions on some machine-readable medium, such as a mark sense card or sheet, hands it in, and receives the next assignment. The whole operation can be almost as fast as on a time-sharing system. The Navy Computer-Managed Instruction System operates in this manner (Carson, Graham, Harding, Johnson, Mayo, & Salop, 1975).

If the turnaround time of a batch system is on the order of hours, rather than minutes, then it is more efficient to change the mode of operation. An operator periodically runs a job that prints out the next assignment and/or quiz for each student. Students pick up their printout at random times, and the result of their work is processed the next time CAISMS is run. Instead of knowing the outcome of his quiz immediately, the student would see it a few hours later.

The cost of running a short job on most batch systems ranges from a fraction of a dollar to a few dollars. In the first mode of operation, a typical figure for each use of CAISMS by a single student is \$.50. In the second mode, a job for processing the work of 100 students and for updating their status might cost a few dollars. However, if the cost of an operator is taken into account, then the second mode of operation might not be cheaper, since an operator would have to collect the student's work, separate the printouts, and distribute them. Hence, we will assess the cost of a student's encounter with CAISMS at \$.50 for both modes of operation on a batch system.

A driver program for running CAISMS on a batch system would consist of 500 to 1000 FORTRAN statements, and could be written by a competent programmer in a few months' time. The above cost estimates are based entirely on programming and equipment costs. In this case, programming would be a few man-months, and equipment would be rented so there would be no purchase costs. Vendors capable of supplying the necessary service are available. The cost of field testing would be almost identical to the above running costs, since, in that case too, equipment should be on a rented (pay as you consume) basis, and almost all programming would have to be done previous to field testing. Estimates might change due to smaller numbers of students in a field test.

Time-Sharing System

On almost any time-sharing system, CAISMS can be operated in exactly the same way that it operates on PLATO, except that most commercial time-sharing systems have a somewhat slower response time. The two main advantages

a time-sharing system has over a batch system are: (1) the student gets immediate feedback, and (2) it is possible to run CAISMS without having any person involved in the logistics of giving, checking, and recording quizzes.

The cost of commercial time-sharing systems ranges from \$4 to \$10 per hour of connect time (Auerbach, 1974). The cost of on-line storage for CAISMS data bases is small compared to the cost of terminal usage (from \$10 to \$100 for 10^6 characters per month, which is the storage capacity we have estimated as being sufficient for a typical CAISMS course). Assuming that a student's encounter with CAISMS lasts 15 minutes on the average, such a session would cost from \$1 to \$2.50.

Implementation would be almost identical to implementation on a batch system (a FORTRAN program would be almost identical on either system), taking a few man-months to program. The above costs estimates are made under the same assumptions as for a batch system. Again, the equipment is rented, so field testing will cost about the same as real use. There would be no equipment purchase and vendors are available to supply the service. Programming for batch mode would require a few man-months. Item writing and other instructional measurement and development costs are not considered.

Dedicated Minicomputer for a CAISMS Classroom

A minicomputer system consisting of a central processing unit (e.g., one of the smaller Digital Equipment Corporation PDP-11's, a Data General Corporation NOVA, or a Hewlett Packard 2000 series), 16K 16-bit words of memory, and a disk with 10^7 characters could service up to 50 terminals in a time-sharing mode.

The terminals in such a system account for a large part of the costs. A teletype or alphanumeric CRT terminal costs between \$1000 and \$2000. Current costs of the remaining equipment would be between \$20,000 and \$150,000, depending somewhat on memory capacity and disk size.

To compare the cost of a dedicated system to that of a batch or time-sharing system, we will assume that (1) the minicomputer system has a lifetime of 5 years, (2) it is used 40 hours per week, and (3) during this time, half of the terminals are in use (hence, a terminal is used 1000 hours per year). Operational and maintenance costs of such a system would be about \$10,000 per year. Therefore, for 250,000 student contact hours, an hour of student contact time would range from less than \$.50 to about \$.80. Comparably, if only 30 terminals were used, the per hour contact costs would be about one dollar. In other words, a dedicated, special-purpose, time-sharing system can be several times cheaper than a commercial service.

In attempting to implement a dedicated system of this sort, the preferable option is to purchase a commercially available minicomputer along with a general-purpose, time-sharing system that can support the CAISMS functions. Under such an option, the implementation would require only a few man-months of programming (as was described for the commercial batch or time-sharing system). In fact, NAVPERSRANDCEN has a version of CAISMS operating on a PDP-11/45 in San Diego. The operating system is the UNIX time-sharing system (Richie & Thompson, 1974) and the CAISMS program was written in the

"C" language in 3 man-months. Documentation is in preparation (Jan 1978) as a NAVPERSRANDCEN Special Report. From this experience, it appears that CAISMS could be supported efficiently by a system composed of a PDP-11/35 (costing about \$30K) with 2 x 10⁶ bytes of disk storage (costing about \$20K), the UNIX operating system (purchased for \$6.7K), and up to 50 terminals (each costing \$1K). This system would function without appreciable delays for students and could be programmed for multiple courses. Including the operating costs over 5 years, the student contact hourly costs would be about \$.60. If only 30 terminals were used, the contact hour costs would rise to about \$.90.

Alternatively, because of the limited and uniform demands that CAISMS makes on the computer, it is possible to procure hardware and develop an efficient, special-purpose, time-sharing system that runs CAISMS more efficiently. This might be realized in faster response times and/or an ability to service additional terminals or use a somewhat powerful central processor. However, it would require about 2 man-years to develop the programs, thereby adding substantially to the student contact hour costs. In addition, other capabilities normally available in a commercial operating system would not be available. Finally, any changes in CAISMS programs would require somewhat greater programming efforts.

Personal Microcomputer

The recent development of processors on a chip has made it possible to consider seriously a personal stand-alone microcomputer system for running CAISMS. It could be an attachment to an ordinary TV set, consisting of a microcomputer, perhaps 8K characters of memory, a cassette or floppy disk for storage, and a keyboard (not necessarily a full typewriter keyboard). A CAISMS course would be mailed to the student on cassettes or a floppy disk and he could work in his room.

The costs of such a system are highly dependent on the number of units that are produced, and on whether they are based on today's costs or those that can be expected in 3 years' time. At today's costs, the various components that go into such a system could be bought for about \$2000 to \$3000, at original equipment manufacturer prices. It is reasonable to expect that, if this system were produced in quantities of several hundred, one such system would cost less than \$500 within a few years.

The development of the hardware and software for such a personal microcomputer system would require a team of a few people, including a competent system designer, working for a few years. The cost estimates above are based on the assumption of a tailor-made design, but include the design and development costs.

The capabilities of a single-user system based on a microcomputer should not be underestimated. Single-chip microprocessors are general-purpose, programmable devices with processing speeds well in excess of what a single CAISMS user will need. The most significant limitation of, and the main difficulty in, designing such a system in the price range of a few thousand dollars, is that it will have a small central memory. Cost estimates in this mode require considerable explication. The estimate of \$2000 to \$3000

per unit today, and less than \$500 per unit (when produced in quantity) in a few years are based on the cost of hardware and assembly, assuming hardware choice decisions and assembly procedures are already made and tested. These costs, therefore, do not include the cost of two to three persons working for 2 to 3 years on new software development (which might include logic, compiler, and I/O design) and new hardware development. Nor do they include the cost during that time of purchase (for testing) or a wide range of equipment components. After this 2- to 3-year process and the testing and finalization of software/hardware, microcomputer units may be produced in large quantities for, we expect, about \$500 each.

Field testing costs are a very difficult question in this case. It might be feasible on existing (and very expensive) general-purpose microcomputers, or by simulation on time-sharing facilities. In any case, the cost for field testing of this mode would be considerable, and has not been included in the estimates.

Instructional development, measurement, and evaluation could be at the same level as the previous modes. The potential for flexible individualized instruction, however, is much greater in this mode and users would probably want to consider its use simultaneously for more than just CAISMS delivery. If that is the case, cost for instructional development, testing, and evaluation would be much greater, with correspondingly larger instructional benefit.

SOME REPRESENTATIVE COURSES USING CAISMS

Having looked at the functions of CAISMS and its implementation on various hardware systems on a theoretical level (i.e., independent of any real curriculum which it might deliver), let us now consider the implementation of CAISMS in a large university lecture course, a small community college course, and in two Navy technical training courses.

Introductory Level University Course

At the University of Illinois, CAISMS has been used for four semesters in a large lecture course on introductory economics. Traditionally, this course has been structured in at least two ways. One way focuses on the main instructor, who lectures to a very large group (up to 300 students) once a week. Several teaching assistants (about four) meet with smaller sections of that group (about 35 students per section) once or twice a week to discuss the lectures, give quizzes and exams, etc. Alternatively, the entire course may be handled in large groups of 75 students each, meeting two or three times a week with a professor or teaching assistant. All lectures, discussion, and testing occurs within this same group.

The course generally has a required text, with 400 to 500 pages of required reading divided into three or four major sections. Each section is followed by an hourly examination or the final exam. There are usually a few short outside readings, which are also tested on exams.

In the first two semesters using CAISMS in this course, all aspects of the course remained the same except that reading of the required text was managed with CAISMS. Although course grades were not computed using performance scores on the study management quizzes, each quiz had to be passed (criterion reached) and specific quizzes had to be completed before students were eligible to take examinations. This implementation of CAISMS had 63 quizzes and required about 190,000 bytes (of disc storage) for question, answer, and assignments files, 15,000 bytes for program storage, and 25,000 bytes of disc storage for all on-line material.

In the following semesters, three times as many students taking the course were given CAISMS with the addition of many new on-line and off-line components. With the addition of on-line examinations, communications, scheduling, progress reporting, etc., the storage of items (600,000 bytes), programs (150,000 bytes), and student records and general data (300,000 bytes) totaled about 1,000,000 bytes (or four times that of the semesters with study management alone).

Introductory Level Community College Course

CAISMS was also implemented for one semester in a community college American history course. This was a relatively small class (about 25 students) with one instructor. One primary text was used. The course has two or three examinations and occasionally requires a paper or project. It represents a small-scale implementation of CAISMS bordering on or just below the lowest figures previously noted. About half of a 400-page text was divided into about 20 quizzes averaging four or five items each. Performance on the quizzes was

not used in the computation of course grades, but quizzes had to be completed before taking exams. Only assignments, quizzes, student record files, and the programs to handle them were involved. The programs and files occupied about 75,000 bytes of storage--about one third of that required for CAISMS in the economics course. Of that storage, 45,000 bytes was for assignment, question, and answer files; 10,000 bytes was for student record files; and 15,000 bytes was for driver programs.

Navy Training Courses

Our main interest here is in future implementation of CAISMS in other courses of other forms. In Navy courses, "other forms" may range from the very lengthy series of instructional modules in the Navy air conditioning and refrigeration school, down to much shorter courses such as the Navy course on Interior Communications (IC). The former course has a total of about 2500 pages of text and 25 examinations, while the latter compares, in amount of text and exams, to typical university level courses. Although it is impossible to talk about CAISMS in the "typical" Navy course (due to this great diversity in length and instructional content), we will get an idea of the range of its implementation by considering its implementation with respect to the two Navy courses mentioned.

The 2500 pages of text required by the Navy air conditioning and refrigeration school are divided into 11 modules and tested by 25 exams. These modules include self-instructional programs, regular tests, problem-solving sections, and other types of instruction. The time span for such a sequence is presumably greater than most university courses, and the student workload for the course is probably more intensive.

The management of study for this amount of off-line text would require a very large amount of storage for quiz items alone. However, one should not look for a direct page to quiz ratio; some material is important and complex enough to require frequent testing, while other material may require only one quiz for an entire chapter. The first module in the air conditioning and refrigeration school program is designed to introduce the student to the material and would not require intensive quizzing. Advanced topics found later in the material require more detailed quizzes to keep the student and instructor informed about how well the student understands the material. The management of this sequence might require as many as 200 quizzes. The storage estimate in this case would be about three or four times that of CAISMS as implemented in introductory economics, or about 1,000,000 bytes of storage for assignments, quizzes, recordkeeping, and the concomitant programs (using about 600,000 bytes for the various quiz-related files and programs, and from 10,000 to 100,000 bytes for records on 100 students, depending on how much data the instructor wishes to collect).

Consider, on the other hand, the IC School. This sequence lasts 8 weeks and covers the same or a little more than the typical university course (in terms of amount of text read). Such a course could be handled at the average of our various disc storage estimates. Assuming about 75 quizzes were used, the course would require some 250,000 bytes for assignment, quiz, and answer files; from 10,000 to 100,000 bytes for student record storage (for 100 students and again depending on what data instructors wish to collect); and about 15,000 bytes for program storage--totaling 250,000 to 350,000 bytes.

The material in this course points up another concern in the management of technical courses; namely, the necessity of dealing with diagrams and pictures in the instructional materials. When the instructional materials make frequent use of figures, the management of student study of those materials will frequently require the students' interaction with figures. In some ways, graphical representations need to be integrated with the text presented to the student by the computer. If the presentation of graphics is done on line, the requirements placed upon the selection of hardware to deliver CAISMS are greatly increased. On the other hand, graphic representations may be kept off line, in which case the need for more advanced and expensive hardware is reduced. For example, in an electronics course that makes frequent use of schematic circuit diagrams, management quizzes would probably be designed that require the student to look at particular circuit diagrams while answering questions. These diagrams may be computer-generated on the student's terminal (requiring hardware with graphics capabilities) or the student may have a notebook of circuit diagrams that his management quizzes refer to by figure number (allowing the use of less expensive alphanumeric terminals).

Another consideration in the wide variety of Navy training courses is the management of instructional materials other than texts. The assignment procedures of CAISMS (and the automated logistics of a course management system) may be used to coordinate the students' activities among a number of educational media in the scope of a course, while the quizzing procedures facilitate optimal student learning within any one phase, and provide the student with information regarding his progress. One might want to coordinate and manage some combination of books, filmstrips, videotapes, CAI materials, live discussions with instructors, operating of equipment, and audiotapes, to name just a few. The question of managing other CAI materials is an interesting one that can be considered at two levels. First, one may manage CAI materials in a fashion identical to the management of text. Second, because of the possibility of directly interfacing on-line CAI and CAISMS materials (whether or not they are on the same system), one could design much "tighter" management procedures that increase the probability that the student has processed the instructional materials in the way the instructor desires.

Although the costs of CAI are generally greater than those of other educational media, we would not consider the added cost of CAI hardware/software as being one of the costs of CAISMS any more than the cost of a traditionally required text or manual is part of the cost. The point remains, however, that a course that makes use of CAI material and uses CAISMS to manage the students' learning from those materials will tend to cost more than a course that makes use of textbooks and uses CAISMS to manage the tests.

The next section describes how the course to be managed and the other instructional factors we have been discussing influence one's choice of a delivery system for CAISMS.

MATCHING THE DELIVERY SYSTEM TO THE AUDIENCE

The choice of a delivery system must be suited to the needs of a particular audience. By this, we mean the size of the class, its work schedule, and the type of instruction.

To see how differences in these aspects can affect the delivery system, consider, first, two courses run in extremely different modes. Course A is offered all year with a steady enrollment, and students' time can be scheduled to put a steady load on the delivery system. In contrast, Course B has an unpredictable and highly variable enrollment and students use the terminals at random times. Which type of delivery system is best in each case?

Most introductory Navy technical courses, such as that on Interior Communications described earlier, fit the description of Course A. Let us assume that a new class of 20 students starts each week, that the course lasts 8 weeks, so that there are a total of 160 students at any moment in all of the classes. Assume that each student requires 2 hours of terminal time per week and that a terminal can be scheduled to be used for 40 hours per week. Under these assumptions, a dedicated system with 10 terminals fills the need of Course A perfectly, and is likely to be the most cost-effective way of delivering CAISMS to an audience with such uniform characteristics.

University courses are sometimes run in a mode similar to Course B and many advanced Navy technical courses are similar. A system devoted solely to one such course would be heavily underutilized. The only cost-effective way to deliver CAISMS to an audience with such irregular habits would be to have them share the resources provided by a large computer with many other users, with the expectation that the cumulative load generated by all users is a more uniform function of time than the load generated by the participants of Course B alone.

A decade ago, the economics of computers was such that it was almost always advantageous to have a large computer shared by as many users as necessary to saturate its capacity. "Grosch's Law," which states that the cost of a computer grows only with the square root of its computational power, was the explanation for this phenomenon. Today, economical aspects favor systems tailored to a homogeneous group of users, even if it is a small group, provided that their demands on the system are predictable and fairly evenly spread over time. This situation applies to many technical training courses offered by the Navy. To illustrate, a moderate size minicomputer delivering only CAISMS might handle 50 terminals (as pointed out earlier). This system might be located in a learning center that is open to different courses at different times (e.g., five 3-hour shifts through the day for five different courses, rotating the schedule throughout the week), so that, when a particular course was in session, only data pertinent to that course would be needed on line. For example, data for each course could be stored on a separate disc pack. Whoever runs the learning center would change disk packs at the end of each shift, inserting the pack appropriate for the course scheduled for the next shift.

In such a scheduled mode of operation, a learning center could service several courses with no greater investment in hardware than it takes to run

one course. If schedules cannot be controlled so tightly, and it is necessary that students in different courses use the system simultaneously, then the system will probably need some additional equipment (e.g., several disk drives and/or more memory).

Because of the nature of a student's interaction with the computer in CAISMS (relatively short sessions), such a system could handle two to four times as many students in the learning center at one time as there are terminals in the center. Most students in the center would be spending their time studying assignments while one-fourth to one-half of the students are working at terminals. Presumably, only a fraction of students in a course would come to the center at one time, so a learning center with such a system (let's say 50 terminals) should be able to handle the 1000 students in five different courses.

Such a system, being entirely devoted to the learning center (in contrast to large-scale systems where there are many other users producing unpredictable system loads), could be scheduled for various other activities at particular times, such as final exams, demonstrations, experiments, or computer programming classes.

Altogether different concerns arise in matching a delivery system to a particular course and audience if we plan to deliver instructional material (CAI) on the computer in addition to study management functions. All the CAISMS functions require only a line-oriented alphanumeric terminal (i.e., the cheapest type of computer terminal on the market) and they can be provided by simple programs requiring only modest amounts of processing power. These two facts allowed us to make relatively precise cost estimates. If we consider the expansion of CAISMS to manage CAI lessons, delivered on the same computer system, the situation becomes much more complicated. CAI lessons (for example, those available on PLATO) differ widely in their requirements on the capability of the terminal, and on the amount of memory and processing. Some types of lessons, such as those based on programmed instruction with text input and output, could be delivered effortlessly on the type of systems we have described. On the other extreme, there are lessons that make extensive use of animated graphics (e.g., in the design of electronic circuits), converse with the student in natural language (e.g., to simulate a command and control task), or contain an elaborate model of some real system (e.g., an aircraft simulator). It is impossible to make cost estimates for the delivery of instructional material of this type without further information about the complexity of the subject matter that is to be presented.

In short, many CAI styles can be delivered using the system we described. On the other hand, equally many other styles, particularly those involving graphics, require significantly more expensive hardware.

CONCLUSIONS

Our conclusions for the implementation of CAISMS on computer systems other than PLATO may be divided into two areas, the short-term effort and the long-term effort.

In the previous section, we indicated that, for the courses with fairly stable enrollment and activity and for the simultaneous (scheduled) management of a number of courses, a dedicated minicomputer system is presently the best bet. To reiterate, the components of CAISMS and its storage requirements place fairly light demands on a computer system. The procedures do not require graphics (though a particular course may find graphics useful), and so require inexpensive terminals. The amount of central processing is small and the storage of material for a course, moderate. The programs for CAISMS are not difficult to write, and are easy to adapt to different courses. Thus, CAISMS could be easily rewritten in most computer programming languages, such as FORTRAN, and would be usable on virtually any computer system supporting FORTRAN, or other common compilers, with only minor program changes. This would be rather straightforward on the small or average size minicomputer system described.

The minicomputer operations described could be implemented on hardware presently on the market with little difficulty. The majority of the effort would probably be in the development of the management materials (quizzes and assignment files). The hardware and software could be assembled and developed and implemented by a competent systems programmer within half a year.

On the other hand, if one is not concerned about getting a working system quickly but is looking toward more flexible systems in the long run, our recommendation is to begin considering the use of microcomputers. The development of a suitable microcomputer system to be used for management functions, as in CAISMS, would require a 2- to 3-year development effort, combining the talents of hardware, software, and courseware specialists and including considerable testing of the final product before implementation in the field.

This direction is an exciting one for a number of reasons. Such a system would permit management of student instruction for students who are not based at a training institute of some sort, but rather, spread out over a large area (such as shipboard students or students at remote bases). It would allow for very portable CAISMS and CMI systems, and for those that are inexpensive enough to allow for student-oriented rather than course-oriented computer systems. A student with such a microcomputer system could receive tapes by mail with course materials for an unlimited number of courses. While the cost of such an individualized stand-alone terminal will inevitably be somewhat higher than the prorated cost for a dedicated time-shared minicomputer system at present, prices of microcomputers are falling rapidly, and there is no reason to assume that the cost of such a single-user system in a few years will be higher than the per-user cost of a time-shared system. Moreover, the single-user system has the potential of reducing costs significantly in certain applications, because certain overhead costs may be eliminated. No operator is needed to run the system, and there may be no need for a separate classroom with terminals.

RECOMMENDATIONS

To summarize, we believe that, in the short term, the best way to implement a management system in one or a number of regularly scheduled courses without much of a development effort would be a dedicated minicomputer system. An evaluation of such an implementation in Navy training is recommended. Concurrent to this implementation, and with an eye towards the future, we recommend research in the development of an inexpensive personalized microcomputer system for the delivery of CAISMS and other forms of course management.

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